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PROTEIN CONTENT OF SOME EDIBLE INSECTS IN MEXICO

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ABSTRACT.–Of the 101 species of edible insects collected and studied in several Mexican states, 77 were analyzed for protein content and evaluated for protein quality. Percent protein varied from a low of about 10% to a high value of slightly over 81%. For many species of insects, protein quality, as evaluated by aminoacid profiles, compared favorably with those recommended for nutritional purposes by FAO/OMS. It is suggested that with appropriate technology and consumer acceptance, commercially produced insect food products would help alleviate hunger and malnutrition.

INTRODUCTION

Entomophagy, the consumption of insects by humans, has long been known, especially in regions where environmental conditions are often adverse (Ancona 1931, 1932, 1934; Blasquez 1870; Bodenheimer 1951; Conconi and Pino 1979; Figueroa 1968; Hoffman 1947; Lapp and Rohmer 1937; Ruddle 1973; Skinner 1910; Thompson 1954; Tihon 1946; Wallace 1852). In fact, in some areas they are a major food source and are even dried and stored in large quantities for consumption when food is scarce. Considering that in some regions different species of insects are available for consumption in different seasons and since the eggs, larvae, nymphs, pupae (grubs), and adults of, for example, butterflies, moths, bugs, flies, ants, bees, beetles, termites, grasshoppers, and dragonflies, are often eaten, a large number of different species of insects are consumed by humans on a worldwide basis.

That hunger and malnutrition is a problem in human populations in many parts of the world is well known. In some instances the problem may not be a sufficient supply of calories but a deficiency of high quality protein. And so the search for new food sources, including the identification and development of localized ethnic ones, continues.

In Latin America food resources are becoming increasingly scarce and the importing of foods is becoming more expensive. It is thus imperative to identify and develop indigenous food resources. In this report of preliminary research we have turned our attention to insects not only because of their abundance, biomass, and high quality protein, but also because of the time honored practice among many culturally diverse peoples of Latin America of consuming live, roasted, and fried insects, providing them with a nutritious protein source.

MATERIALS AND METHODS

Collection and identification.—The insects for which nutritional studies were conducted in this report were collected during field work in various parts of Mexico where people regularly use them as food. The stage of the insect life cycle which was eaten was noted in every case. A portion of the collection was preserved in acetone for later chemical analysis and the remainder was placed in alcohol for later taxonomic identification and as vouchers.

All specimens were identified at the Laboratory of Entomology, Institute of Biology, The National University of Mexico (U.N.A.M.) in Mexico City, through the use of the taxonomic literature and reference collections.

Chemical and nutritional analyses.—Aminograms were prepared by the Department of Nutrition Physiology of the "Salvador Zubiran" National Institute of Nutrition of Mexico. All other analyses were performed at the Laboratory of Nutrition and Biochemistry of the Veterinary Faculty of U.N.A.M.

Protein content was determined by the Kjeldahl method (Pearson 1970), with the results calculated on a dry weight basis. Aminoacids were measured with an aminoacid analyzer (Beckman CL 119) with the aid of a minicomputer (Beckman model 126 Data System) designed to integrate peak areas of chromatograms. Tryptophan measurements were obtained by the Spies and Chamber (1949) method. Aminoacid profiles were compared to those recommended by FAO/OMS (Patron 1973), and a "chemical score" of aminoacid profiles based on 100% was devised to give us an index of protein quality.

Trejo et al. (1974) interviewed scientists, chefs, and consumers in Mexico City to determine the acceptability of commercially produced insect food products.

RESULTS AND DISCUSSION

Conconi and Bourges (1977) reported in that year that 491 species of edible insects had been recorded on a worldwide basis. During our research in Mexico we recorded 101 species, eaten at various stages of development depending upon the species. These belonged to 31 families in nine orders and included dragonflies, grasshoppers, bugs, lice, treehoppers, cicadas, caddishflies, butterflies, moths, flies, ants, bees, and wasps (Appendix 1). The number of edible species per order varies from 30 in the Hymenoptera (mostly wasps) to only one in the Anoplura (lice). A couple of interesting facts, not apparent in Appendix 1, deserve special comment: eggs are the stage consumed in the aquatic bugs (Corixidae, Notonectidae, and Belostomatidae), and two of the three species of edible Diptera are flies of alkaline lakes.

Protein content, expressed as grams of protein per 100 g of sample, for the 77 species of insects we analyzed, is shown in Appendix II. The data is straight forward and one can readily note the range in nutritional values within and between insect taxa. It is worth highlighting, though, that protein values varied from a low of about 10% for two species of ants to a high of slightly over 81% for the wasp, *Polybia sp.* By way of summary, seven species in the low range had about 29% protein, 19 species fell within the range of 60% to 69%, 11 species from 70% to 77%, and one species had over 81% protein.

Several incidental but nonetheless interesting facts seem worth comment. Two species of butterfly in the family Helialidae utilize *Arbutus glandulosa* as a host tree and they exhibit the lowest (34.34%) protein values and the highest (71.60%) in that family. These values are for *Hylesia frigida* and *Eucheria socialis,* respectively. In the Hemiptera the highest value is for the eggs of several bugs (71.52%), known as "ahuahutle" or Mexican caviar.

Protein quality, as related to human nutrition, is dependent upon the amino acid composition of the source, and we devised a chemical score (Table 1) from aminoacid profiles to facilitate comparisons (see Methods). As noted, our profiles were compared to those recommended (for nutritional purposes) by FAO/OMS (Patron 1973). In general, values for Mexican edible insects obtained for the amino acids isoleucine, leucine, lycine, threonine, valine, phenylalanine and tyrosine surpass the recommendation by FAO. Some Mexican insects, however, had lower values for methionine, cysteine and tryptophan than those recommended by FAO/OMS. The highest score for Mexican insects was found in immature queens of *Liometopum apiculatum*, larvae of *Sciphophorus acupunctatus* and adults of *Hoplophorion monograma* (Conconi and Bourges 1977, Table 1).

TABLE 1.—*Chemical score of some edible Mexican insects.*

Atizies taxcoensis	10%	*Sphenarium histrio*	60%
Ephydra hians	42%	*Cossus redtenbachi*	60%
Hylesia frigida	45%	*Atta mexicana*	60%
Parachartegus apicalis	50%	*Sphenarium purpurascens*	65%
Euchistus strennus	56%	*Vespula squamosa*	70%
Boopedon flaviventris	56%	*Brachygastra mellifica*	70%
Sphenarium spp.	56%	*Brachygastra azteca*	70%
Melanoplus mexicanus	56%	*Polybia parvulina*	70%
Trigona sp.	58%	*Liometopum apiculatum*	80%
Musca domestica	58%	*Sciphophorus acupunctatus*	81%
Pachilis gigas	58%	*Hoplophorion monograma*	96%

The conversion efficiency ratio is based on weight gain by the organism per gram of food eaten. For some edible insects this ratio ranges from 2.1:1 to 11.8:1. The average ratio for the edible insects studied is about 4 to 5:1. For comparison, the ratio for chickens is 2.6:1, for beef cattle 10:1, and for sheep 19:1 (Taylor 1975, DuFour 1981). In part this is because insects are poikilotherms and thus do not allocate a large proportion of food in maintaining body temperature.

As early as a decade ago Trejo et al (1974) interviewed 12,300 people (see Methods) concerning the acceptability of commercially produced insect food products and reported that in this survey 93% indicated that developing insects on a commercial scale was a good project considering that insects are, in general, a nutritious, economical, delicious, complete food, and "in the future."

The result of this study and the survey by Trejo and others suggests that with improved technology insects could be a valuable renewable natural resource. The establishment of massive culturing practices could result in the continuous production of a rich new protein source for the diets of people in the not too distant future.

Editor's note.—Although I would have liked a more detailed description of the methods used, I have decided to publish this paper because of the timeliness of the subject and because of its considerable social significance. I recommend that readers who would like details of methods and other procedures contact the senior author.

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APPENDIX 1.–*Edible insects in Mexico.*

Order/Family	Species	Stage Consumed	Place Consumed
Odonata (Dragonflies)			
Aeshnidae	*Anax sp.*[1]	nymphs	Sonora
Orthoptera			
Acrididae	*Ochrotettix cer salinus* Burm.		Oaxaca
(Grasshoppers)	*Tropinotus mexicanus* Brunner		Oaxaca
	Osmilia flavolineata De Greer		Oaxaca
	Plectrotettra nobilis Walk		Oaxaca
	Schistocerca paranensis[1] Burm.		Veracruz, Tabasco, Campeche, Yucatan
	Sphenarium spp.[1]		Morelos, Puebla, Oaxaca
	Sphenarium purpurascens Charp.	nymphs	Oaxaca
	Sphenarium histrio[1] Gerst.	adults	Oaxaca, Guerrero
	Sphenarium magnum Marquez		Oaxaca
	Taeniopoda sp.[1]		Morelos
	Trimerotropis sp.[2]		Hidalgo
	Melanoplus sp.		Oaxaca
	Melanoplus mexicanus Sauss		Oaxaca
	Spharagemon aeguale Say.		Michoacan
	Schistocerca sp.		Oaxaca
	Boopedon flaviventris Sauss.		Oaxaca
	Boopedon sp. af. flaviventris Sauss.	nymphs adults	Oaxaca
	Arphia falax Sauss.		Oaxaca
	Encoptolophus herbaceus Sauss.		Oaxaca
Anoplura (Lice)			
Pediculidae	*Pediculus humanus*[1] Linneo	adults	Oaxaca
Hemiptera (Bugs)			
Pentatomidae	*Euchistus crenator*[1] Stal		Morelos, Estado de Mexico, Hidalgo, Veracruz, Guerrero
Common Name ("Jumiles")	*Euchistus lineatus*[1] Walk		Morelos, Estado de Mexico, Hidalgo, Veracruz, Guerrero
	Euchistus strennus[1] = (E. zopilotensis) Distant	nymphs adults	Morelos, Estado de Mexico, Hidalgo, Veracruz, Guerrero
	Edessa mexicana[1] Stal.		Morelos
	Edessa petersii Stal.		Guerrero
	Edessa conspersa Stal.		Estado de Mexico
	Atizies taxcoensis[1] Ancona		Guerrero
	Atizies sufultus Smith		Guerrero

APPENDIX 1.—*Edible insects in Mexico* (continued)

Order/Family	Species	Stage Consumed	Place Consumed
Coreidae	*Pachilis gigas*[1] B.	nymphs adults	Queretaro, Guerrero, Hidalgo, Sn. Luis Potosi
Corixidae (Water Bugs)	*Krizousacorixa azteca*[1] Jac.	eggs	Estado de Mexico, Guanajuato, Michoacan
Common name ("ahuahutle" "axayacatl")	*Krizousacorixa femorata*[1] Guerin	nymphs	Estado de Mexico, Guanajuato, Michoacan
	Corisella texcocana[1] Jac.	adults	Estado de Mexico, Guanajuato, Michoacan
	Corisella mercenaria[1] Say		Estado de Mexico, Guanajuato, Michoacan
Notonectidae	*Notonecta unifasciata*[1] Guerin	adults	Estado de Mexico, Guanajuato, Michoacan
Belostomatidae	*Lethocerus sp.*[1]	nymphs	Distrito Federal
	Abedus ovatus[1] Stal.	& adults	Distrito Federal
Homoptera			
Membracidae (Treehoppers)	*Umbonia reclinata* Germar	adults	Puebla
	Umbonia sp.	nymphs	Morelos, Guerrero
	Hoplophorion monograma[1] Germar	& adults	Michoacan, Guerrero, Estado de Mexico
Cicadidae (Cicadas)	*Proarna sp.*[2]	adults	Hidalgo
Coleoptera (Beetles)			
Curculionidae	*Metamasius spinolae*[1] Vaurie		Hidalgo
	Rhynocophorus palmarum[1] Linneo		Tabasco, Guerrero, Veracruz
	Sciphophorus acupunctatus G.		Hidalgo, Estado de Mexico, Oaxaca
Scarabaeidae	*Strategus sp.*[1]	larvae	Nayarit, Chiapas
	Phyllophaga spp.[1]		Michoacan
	Xyloryctes spp.[1]		Chiapas
Crysomelidae	*Leptinotarsa decemlineata* Say	larvae	Oaxaca
Histeridae	*Homolepta sp.*	larvae	Oaxaca
Passalidae	*Oileus reinator* Trequi	larvae	Oaxaca
	Passalus af punctiger Lep. y Serv.	larvae	Oaxaca

APPENDIX 1.—*Edible insects in Mexico* (continued)

Order/Family	Species	Stage Consumed	Place Consumed
Cerambycidae	*Cerambyx sp.*[1]	larvae	Michoacan, Guerrero
	Trichoderes pini[1] Chevr.	larvae	Guerrero, Michoacan
	Stenodontes cer. maxillosus Drury	larvae	Oaxaca
	Aplagiognathus spinosus N.	larvae	Oaxaca
Cicindelidae	*Cicindela curvata*[1] Chevr.	larvae	Chiapas
	Cicindela roseiventris[1] Chevr.	larvae	Chiapas
Trichoptera			
Hydropsichidae	*Leptonema sp.*[1]	larvae	Veracruz
Lepidoptera (Butterflies and Moths)			
Megathymidae	*Aegiale* (Acentrocneme) *hesperiaris*[1] Kirby	larvae	Estado de Mexico, Hidalgo, Tlaxcala, Queretaro, San Luis Potosi, Oaxaca, Jalisco, Distrito Federal.
Geometridae	*Synopsia mexicanaria* Walk	larvae	Distrito Federal
Hepialidae	*Phassus* sp.	larvae	Oaxaca, Puebla
Noctuidae	*Heliothis zea*[1] Boddie	larvae	Puebla, Hidalgo
	Ascalapha odorata[1] Linneo	larvae	Oaxaca, Guerrero
	Spodoptera frugiperda S.	larvae	Estado de Mexico
Cossidae	*Xileutes redtenbachi*[1] Hamm	larvae	Estado de Mexico, Hidalgo, Tlaxacala, Queretaro, Puebla, San Luis Potosi, Oaxaca, Jalisco, Distrito Federal.
Pyralidae	*Laniifera cyclades*[1] Druce	larvae	Hidalgo
Pieridae	*Eucheria socialis*[1] Westwood	larvae	Distrito Federal, Chihuahua, Hidalgo
	Catasticta teutila Doubleday	larvae	Oaxaca
Saturnidae	*Hylesia frigida* Hubner	larvae	Oaxaca
	Arsenura armida Cramer	larvae	Puebla, Oaxaca, Veracruz, Chiapas
Diptera (Flies)			
Ephydridae	*Ephydra (Hydropyrus) hians*[1] (Say) Cresson	larvae	Estado de Mexico
	Gymnopa (Mosilus) tibialis[1] Cresson	larvae	Estado de Mexico
Muscidae	*Musca domestica* Linneo	larvae	Nayarit, Veracruz

APPENDIX 1.—*Edible insects in Mexico* (continued)

Order/Family	Species	Stage Consumed	Place Consumed
Hymenoptera			
	Liometopum occidentale var. *luctuosum* W.	eggs larvae pupae	Michoacan, Puebla Zacatecas
Formicidae (Ants)			
	Liometopum apiculatum[1] Mayr.	eggs larvae pupae	Estado de Mexico, Hidalgo, Tlaxcala
	Myrmecosistus melliger[1] Llave (Luc)	adults	Tamaulipas, Hidalgo
	Myrmecosistus mexicanus[1] W.		Yucatan, Campeche
	Atta mexicana[1] Bourmeir	adults	Veracrus, Oaxaca, Guanajuato
	Atta cephalotes[1] Latr.		Chiapas, Guerrero
Apidae (Bees)			
	Apis mellifica[1] L.	honey	All Mexican Republic
	Melipona fasciata guerreroenisis[1] Schw.	eggs	Guerrero
	Melipona beeckei[1] Bennet	larvae	Yucatan
	Trigona jaty[1] F.	pupae	Oaxaca, Tabasco, Campeche, Yucatan
	Trigona nigra nigra[1] Cress		Oaxaca, Tabasco, Campeche, Yucatan
	Partamona sp.[1]		Campeche, Yucatan
	Trigona sp.		Oaxaca
	Lestrimelita limao[1] Sm.	eggs pupae larvae	Campeche, Yucatan
Vespidae (Wasps)			
	Brachygastra lecheguana[1] L.	eggs larvae pupae	Michoacan
	Brachygastra mellifica Say	immature stages	Oaxaca
	Polybia spp.	eggs	Oaxaca Michoacan
	Polistes sp.	larvae pupae	Michoacan

APPENDIX 1.—*Edible insects in Mexico* (continued)

Order/Family	Species	Stage Consumed	Place Consumed
	Polybia occidentalis bohemani Holmgren		Oaxaca
	Polybia occidentalis nigratella B.		Oaxaca, Michoacan, Veracruz, Puebla
	Polybia parvulina Richards	immature	Oaxaca
	Brachygastra azteca Sauss	stages	Oaxaca
	Mischocytarus sp.		Oaxaca
	Parachartegus apicalis F.	immature	Oaxaca
	Polistes canadensis L.	stages	Oaxaca
	Polistes major B.		Michoacan
	Anmophila sp.		Oaxaca
	Vespula squamosa Drury		Oaxaca

[1]Conconi, J. R. E. de and H. Bourges, 1977.

[2]Conconi, J. R. E. de and J. M. Pino M., 1979.

APPENDIX 2.—*Protein content of insects, expressed as a percentage of grams of protein per 100 grams of sample on a dry weight basis.*

Species (arranged in orders)	Common Name, Stage Consumed Notes	Percent Protein
Hymenoptera (Ants, Bees, Wasps)		
Myrmecosistus melliger	"hormiga mielera", "honey ant"[2]	9.45%
Myrmecosistus mexicanus	"hormiga mielera", "honey ant"	10.5%
Melipona beeckei	"abeja que no pica"	28.95%
Liometopum apiculatum	"escamol", larvae	37.33%
Liometopum occidentale var. luctuosum	"escamol", adults	37.54%
Liometopum apiculatum	"escamol de obreras"	40.90%
Liometopum occidentale var. luctuosum	"escamol de reproductores"	41.68%
Atta cephalotes	"hormiga arriera"2	42.59%
Liometopum apiculatum	"escamol", adults	45.06%
Liometopum apiculatum	"escamol", adults	45.53%
Liometopum occidentale var. luctuosum	"escamol de obreras"	48.28%
Polybia sp.	"avispas" larvae	51.50%
Brachygastra mellifica	"avispas, panal de castilla"	52.84%
Liometopum apiculatum	"escamol", pupae	53.32%
Parachartegus apicalis	"avispa ala blanca"	54.59%
Polistes instabilis	"avispa guitarrilla", pupae	57.75%
Polistes major	"avispa coloradad", pupae	57.93%
Atta mexicana	"hormiga chicatana"1	58.3-42.59%
Polistes instabilis	"avispa guitarrilla", larvae	60.00%
Polybia parvulina	"avispa negra"	61.40-58.44%
Polybia occidentalis bohemani	"avispa rayada"	61.57%
Brachygastra azteca	"avispa cola amarilla"	62.74%
Vespula squamosa	"avispa panal de tierra"	62.85%
Polybia occidentalis nigratella	"avispa huevo de toro"	62.93%
Polybia sp.	wasps eggs, larvae, pupae	62.97%
Liometopum apiculatum	"escamol", larvae y pupae	66.90-47.94%
Polistes major	"avispa colorada" larvae	71.99%
Mischocytarus sp.	"avispa negra con franjas"	74.51%
Polybia sp.	"avispa negra"	81.69%
Orthoptera (Grasshoppers,) "chapulines"		
*Sphenarium histrio*1		52.13%
Plectrottetra nobilis		58.31%
Sphenarium histrio		58.31%
Sphenarium purpurascens		58.31%
Melanoplus sp.		58.31%
Sphenarium magnum		59.63%
Sphenarium histrio = bolivari1		62.93%
*Trimerotropis sp.*2		65.13%

APPENIX 2.—*Protein content of insects, expressed as a percentage of grams of protein per 100 grams of sample on a dry weight basis.* (continued)

Species (arranged in orders)	Common Name, Stage Consumed Notes	Percent Protein
Sphenarium sp.		69.97%
Taeniopoda sp.		70.92%
Arphia falax		71.35%
Boopedon sp. flaviventris		71.35%
Sphenarium sp.		71.35%
Melanoplus mexicanus		71.35%
Encoptolophus herbaceus		71.35%
Melanoplus femur-rubrum		75.30%
Boopedon flaviventris		77.13%
Sphenarium spp.		77.13%
Melanoplus mexicanus		77.13%
Hemiptera (Bugs)		
Edessa conspersa	"jumiles"	36.82%
Atizies sufultus		44.10%
Edessa mexicana	"jumiles"	44.10%
Euchistus zopilotensis = strennus	"jumiles"	44.10%
Euchistus zopilotensis	"jumiles"[1]	44.67-41.82%
Edessa petersii	"jumiles"	58.56%
Pachilis gigas	"chamoes", nymphs[2]	62.95%
Pachilis gigas	"chamoes", adults[2]	65.39%
Abedus ovatus	"cucarachon de agua"	67.69%
Corisella mercenaria	"axayacatl"[1]	68.70%
Corisella texcocana		69.94-54.44%
Corisella mercenaria		69.96-54.44%
Notonecta unifasciata	"axayacatl"	69.96-54.44%
Krizousacorixa azteca		69.94-54.44%
Krizousacorixa femorata		69.94-54.44%
Atizies taxcoensis	"jumiles de Taxco"[1]	70.30-51.25%
Corisella texcocana		71.52-58.25%
Corisella mercenaria		71.52-58.15%
Notonecta unifasciata	"ahuahutle"	71.52-58.15%
Krizousacorixa azteca		71.52-58.15%
Krizousacorixa femorata		71.52-58.15%
Homoptera (Treehoppers, Cicadas)		
Umbonia reclinata	Torito	32.73%
Hoplophorion monograma	periquito del aguacate	59.57-44.84%
Proarna sp.	chicharra[2]	72.02%

APPENDIX 2.—*Protein content of insects, expressed as a percentage of grams of protein per 100 grams of sample on a dry weight basis.* (continued)

Species (arranged in orders)	Common Name, Stage Consumed Notes	Percent Protein
Diptera (Flies)		
Ephydra (Hydropirus) hians	"gusano del agua", larvae	35.90%
Fam. Stratiomydae y syrphidae	"gusanos planos de maguey"	53.70%
Musca domestica	"gusano del queso," larvae	54.17%
Ephydra (Hydropirus) hians	"mosca del agua", adults	60.22%
Musca domestica	"gusano del queso", pupae	61.54%
Coleoptera (beetles)		
Olleus reinator	"ticoco"	20.91%
Aplagiognathus spinosus	"gusanos de elite podrido"	26.25%
Passalus af. punctiger	"bechano"	26.42%
Phyllophaga sp.	"gusano de la tierra"	29.68%
Sciphophorus acupunctatus	"picudo del maguey"	55.56%
Metamasius spinolae	"picudo del nopal"[2]	69.05%
Lepidoptera (butterflies and moths)		
Phassus sp.	"gusanillo"	34.34%
Xyleutes redtenbachi	"gusano rojo de maguey"	37.10-71.00%
Hylesia frigida	"mariposa del madroño"	41.93%
Heliothis zea	"gusano de maíz"[2]	41.98%
Synopsia mexicanaria	"pescaditos"	44.48%
Laniifera cyclades	"gusano del nopal"[2]	45.83%
Acalapha odorata	"Mariposa del muerto"	50.83%
Eucheria socialis	"gusano del madroño", larvae[2]	50.88%
Aegiale (acentrocneme) hesperiaris	"gusano blanco de maguey"[2]	51.00-30.28%
Arsenura armida	"gusano del jonote"	51.81%
Catasticta teutila	"gusano del muérdago"	66.58-59.78%
Eucheria socialis	"mariposa del madroño", pupae	71.60%

[1]Conconi, J. R. E. de and H. Bourges, 1977.

[2]Conconi, J. R. E. de and J. M. Pino M., 1979.